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INFRARED IMAGERY RECOGNITION PROCESSING

by

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INFRARED IMAGERY RECOGNITION [AND] PROCESSING

Abstract: This document addresses in simple terms the flow of information in infrared imagery recognition and processing, and proposes using knowledge-based expert systems and advanced neural networks to bring about a development direction for automated, intelligent imagery recognition and processing. This document also presents a kind of effective missile-borne infrared imagery detection, tracking, and extrapolation method.

Key terms: infrared, imagery recognition, imagery processing

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I. FORWARD

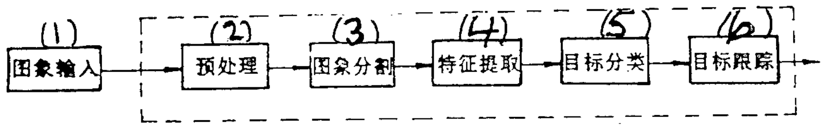
Infrared imagery recognition processing systems are indispensable component parts of infrared imagery guidance heads. They belong to one of the key technologies in precision guidance systems. In modern defense technology, they possess an important place, and they are one of the signs of weapon system automation, conversion to intelligence, and even weapon system replacement. Infrared imagery recognition processing research contents are extremely abundant--for example, infrared imagery sequence processing, low signal to noise ratio detection, target invariable characteristic analysis and extraction, recognition of targets against complicated backgrounds, real time information processing technology making special use of conversion to intelligent target recognition associated with expert systems and neural networks as well as the completion of the contents of research discussed above, and so on.

II. Infrared Imagery Recognition Processing Flows as Well as Ways of Actualization

As far as infrared imagery recognition processing flows are concerned, normally, they are divided into the five parts of preprocessing, imagery division, characteristic

* Numbers in margins indicate foreign pagination. Commas in numbers indicate decimals.

extraction, target classification, and target tracking. The flow chart is as shown in the Fig. below:



Infrared Imagery Recognition Processing Flow Chart (1) Imagery Input (2) Preprocessing (3) Imagery Division (4) Characteristics Extraction (5) Target Classification (6) Target Tracking

1. Preprocessing

Preprocessing primarily includes wave filtering and multiple target detection. As far as fighting under the conditions of bad battlefield environments is concerned, due to target infrared radiation being relatively weak, it is necessary to filter out noise and environmental interference in the infrared imagery, increasing the effectiveness and reliability of target detection and recognition, and, in conjunction with this, creating good conditions for imagery division. At the present time, what is most commonly seen is the option to use false middle value wave filters. It possesses the advantages of restraining noise and increasing signal. Moreover, it is easy to use hardware and software to realize.

Multiple target detection is a prerequisite for target recognition. From time order imagery, a rapid decision is made on whether or not targets exist in the area. In conjunction with this, initial fixing is realized on targets that appear. High brightness points in detection imagery act as target candidates. In conjunction with this, through open windows, it was possible to very, very greatly reduce the amounts of calculations.

2. Imagery Division /51

Imagery division is nothing else than--in accordance with certain characteristics--taking imagery space and dividing it into a number of regions. Imagery characteristics within the same region are the same. Imagery characteristics of different regions are variously different. The objective is to take the forms of all "possible targets" within windows with target points as centers and divide them out.

Opting for the use of imagery relaxation division methods based on models, before extracting target geometrical characteristics, they will be precisely cut away from the background and extracted. Threshold value processing is carried out, and, in conjunction with that, they are converted to dual values. Moreover, division threshold values are capable of automatic selection in order to adapt external boundary condition changes to the influences of infrared imagery. This type of gate limit characteristic method is only capable of obtaining partial, incomplete target information. The reason is that, during imagery division processes, there will sometimes be produced target edge "cracks" or the appearance of pit phenomena. It is difficult to extract a closed target profile among background noise. Frequently, it is also necessary to opt for the use of methods associated with the combining and division of target region characteristics and edge characteristics in order to synthesize a complete target.

3. Characteristics Extraction

Target characteristic extraction plays an important role in imagery recognition. As a result, it is a key technology for real time imagery tracking systems. It does

not only influence the accuracy of recognition and classification. It, moreover, also influences the algorithms and the speed of calculations. Target characteristics are nothing else than various types of parameters reflecting target attributes. They are digitized and become characteristics data which computers are capable of receiving and are used in order to carry out classification, description, and tracking of recognized objects. Characteristics which can be selected are very numerous--for example, structure characteristics (target two dimensional projection length, width, circumference, area, and so on), statistical characteristics (target mean square deviation, mean values, and so on), and spacial characteristics (target position, speed, distance, and so on). The principles for selecting characteristic digits should be based on the requirements of effective recognition. As much as possible, selection should be made of relatively few numbers in order to reduce the complexity of target classification.

4. Target Classification

Target classification includes "target preclassification processing" (that is, after going through preprocessing, imagery division, and characteristics extraction, the carrying out of marking on targets existing in imagery) and, on the basis of selection characteristics, the execution on the many targets, of tracking, side recognition, and final recognition as real targets or main targets.

Target classification methods are very numerous. Each has special characteristics. For example, methods based on characteristic vector matching possess the advantage of high speed processing. Laminar Manhedun (phonetic) minimum distance methods possess relatively high recognition probabilities. "Neural network like" methods associated

with multidimensional gradients allow one to have relatively large characteristic error ranges.

5. Target Tracking

Before real targets are recognized, multiple target tracking is carried out of target objects in the imagery. At the same time, movement characteristics are supplied constantly to classification devices. Single target tracking only requires supplying target angular deviations. In conjunction with that, error signals are inputed into control systems to carry out corrections, guaranteeing that the center of targets are placed at the center of infrared fields of view. Multiple target tracking should track multiple targets, recording their positions in the field of view. Moreover, as far as the carrying out of tracking of objects in groups is concerned, real time information should also be given on their angular positions. It is possible to opt for the use of characteristic--correlation compensation tracking methods to carry out real time position fixing of various individual targets from sequenced imagery in each frame. After real targets are recognized, they are transformed into single target, self-adapting tracking window tracking configurations. In conjunction with this, through algorithms, precise determinations are made of the positions and speeds. Making use of Kaerman (phonetic) target tracking algorithms based on gradient measurements, iterative substitution approximate target center of mass tracking algorithm methods, target tracking algorithms based on center of gravity vectors, target tracking algorithms after inserting FFT, as well as automatically changed window dimension algorithms, and so on, tracking precision is extremely high. They are capable in all cases of reaching sub image element orders of magnitude.

6. Directions in the Development of Infrared Imagery Processing Technology

Infrared imagery recognition processing is an interesting new technology that began to develop over the last twelve years. With regard to the development of precision guidance technology and space interception technology, they possess key significance. At the present time, it has already become a hot topic in the midst of great efforts at development and research inside China and abroad. Automatic target recognition technology is one of the key technologies which the U.S. Defense Department listed as main points to be developed. As far as the "Youchu (phonetic) [Chinese means a young domestic animal]" infrared imagery guided missile which the U.S. already possesses and the SLAM, which relies mainly on artificial participation for recognition, are concerned--with automation and conversion to intelligent imagery recognition technology--it can be expected to achieve practical applications by the end of this century.

Imagery recognition processing systems turned /52
intelligent should possess such functions as imagery understanding, autonomous planning, formulation of knowledge and reasoning, self-adjusting operation and control, mechanical learning, expert systems, artificial intelligence, and so on. At the present time, development trends are neural network expert systems. Due to neural network methods, it is possible to make effective use of them in imagery division. Target recognition capabilities are strong. Also, due to the fact that they have the characteristics of possessing learning capabilities and permitting large errors, as a result, self-adapting capabilities are relatively strong. They are even more suitable for use with environmental changes and have already

become important points in the direction of development.

At the present time, methods opting for the use of imagery recognition processing are relatively numerous. Generally, they are all capable of achieving relatively good target detection and classification results. The direction for further research is how to raise operating speeds. Actualization is easy. In order to satisfy engineering applications, EKF neural networks, which are in the process of being explored, have hopes of turning into the direction for the main attack.

III. Onboard Infrared Imagery Recognition Processing Methods

There are relatively large differences between infrared imagery recognition processing onboard missiles or shells and ordinary imagery processing devices. First of all, they are a fully automatic imagery processing system. Second, they require that algorithms be simple and reliable. In the entire recognition processing process, taking imagery and matching tracking is the main thing. Target recognition and decisions are secondary. This is because, entering into the target tracking phase, initial infrared information processing has already taken targets and drawn them into infrared fields of view.

1. Infrared Imagery Recognition Processing

From infrared imagery obtained by onboard sensors, generally speaking, relatively strong target data is already included (introduced by initial guidance). The elimination of noise and the extraction of targets from the imagery in question is the first operational step associated with

infrared imagery recognition processing.

Imagery obtained from infrared sensors is capable of being represented using the two dimensional function f(x,y). In conjunction with this, it is possible to divide it into two parts

$$f(x、y) = f_s(x、y) + f_0(x、y)$$

In this, fs(x,y) and fo(x,y) are, respectively, background and target image functions. After taking the imagery functions in question and digitizing them, they are:

$$f(x_i、y_j) = f_s(x_i、y_j) + f_0(x_i、y_j)$$
$$i = 0、1、\cdots M,\ \ j = 0、1、\cdots N$$

Due to background functions generally being capable of using a normal distribution N = (μ,σ) to represent the statistical characteristic of fs(xi,yj), by comparison, target signal ratios are relatively strong. Moreover, when it is a target image fo(xi, yi) possessing a fixed form, it can be represented using the matrix

$$f_0(x_i, y_j) = \left.\underbrace{\begin{pmatrix} 0 & \cdots & \cdots & 0 \\ \vdots & \times & 0 & \times & \vdots \\ \vdots & \times & \times & \times & \vdots \\ 0 & 0 & \times & 0 & \vdots \\ 0 & \cdots & \cdots & 0 \end{pmatrix}}_{N}\right\} M \qquad (1)$$

In form (1) x stands for non zero values. The distribution of non zero values associated with the matrix is the target planar projected accumulation on detectors.

The matrix of background function fs(xi,yj) is expressed in the form:

$$f_s(x_i, y_i) = \begin{pmatrix} S_{00}, & S_{01} \cdots\cdots & S_{0N} \\ & \ddots & \vdots \\ S_{0N} \cdots\cdots & \cdots & S_{NM} \end{pmatrix} \qquad (2)$$

Among these, each element Sij is a distribution N(μ,σ). Due to backgrounds being relatively clean, it is, therefore, possible to postulate the expected values μ,σ being relatively small compared to targets.

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With regard to the processing of this type of infrared imagery, using mathematical statistics methods and putting them together with imagery processing is one type of appropriate consideration (Mathematical statistics treatments are capable of lowering amounts of calculations in a large way. In conjunction with this, quick responses are made to algorithms.)

Because what detection devices detect is the sum of target imagery and background imagery, and also, because average degrees of target contrast are far larger than average degrees of background contrast, it is, therefore, desirable to opt for the use of imagery contrast checks and separations and, in conjunction with that, recognize targets.

Average degrees of contrast within imagery frames can be expressed as:

$$\bar{f} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} f(x_i,\ y_j) \qquad (3)$$

Using multiples of average contrasts f as gate limits, L individual imagery units with relatively strong signals are screened out from frames of imagery.

$$\{f_R\} \qquad R=0,1,2,\cdots\cdots L\text{-}1 \tag{4}$$

The function making measurements for the screening out of {fR} individual image elements is:

$$C\{f_R\}=M\langle f_i,f_j\rangle i、j=0,1\cdots\cdots\cdots L\text{-}1 \tag{5}$$

Note: M<fi,fj> is {fR} position measure.

Using C{fR} measures to act as target shape correlation checks, targets are finally recognized.

What needs to be pointed out is that C{fR} is position measures associated with L individual samples screened out. In reality, it also plays the role of screening out noise because image elements which do not correlate with target shapes will be eliminated.

Going through methods above to check false alarm rates in target recognition, they are on the order of approximately 10-3 sec. Due to the fact that, when infrared sensors operate, the target forms which detectors detect are relatively large. Imagery resolution, therefore, can be a bit low, facilitating simplified algorithms and lowering costs.

Based on our calculations and experiments, the general resolution rate for imagery sensors is 32x32 which is relatively appropriate.

2. Infrared Imagery Tracking Processing

The main task of infrared imagery tracking processing is to switch over to tracking after targets have been identified. Normally, option is made for the use of self-adjusting tracking.

a. Contrast Self-Adjusting Tracking

Let T be contrast operator

$$T = (f(x_i, y_j)) = \{A\}_L \tag{6}$$

In this, A is gate limit for one contrast test. Contrast self- adjustment indicates that the next gate limit value is capable of fluctuating above or below value A in

accordance with a certain coefficient. Using this method, it is possible to improve tracking target drift caused by changes in contrast.

b. Image Criteria Ordered Penetration Correlation Tracking

After checking targets with image recognition processing, the geometrical center of the L individual image elements screened out are calculated out as well as second order moments (target centers of gravity) as imagery criterion St . In conjunction with this, on imagery criteria St for the imagery frame in question as well as the previous imagery frame St-1 , sequenced penetration correlation comparisons are carried out:

$$S_t - S_{t-1} \leqslant \varepsilon \qquad t = 1, 2, \cdots\cdots n \tag{7}$$

ε is tracking deviation. It is precisely determined by system design. When equation (7) is inadequate, tracking switches over into new exploration and recognition.

Sequenced penetration correlation methods are one hot point in recognition and tracking technology inside China and abroad in the last few years. When system design is relatively good, the amounts of calculation and processing are relatively small. Recognition and tracking precision, in all cases, are capable of achieving increases. At the same time, sequenced penetration method convergence characteristics are relatively good. However, it is necessary to correctly select deviation amounts . In conjunction with this, with regard to target statistical parameters (for example, distribution functions, distribution likelihood ratio functions, and so on), there

must be a relatively accurate estimate.

3. Memory Extrapolation Tracking

Memory extrapolation tracking technology is a type of specialized emergency tracking measure. At the present time, a good number of weapons systems outside China possess this type of function. With main attention on times when targets are normally tracked, targets are suddenly blocked and disappear for short periods. After a few seconds, they again normally reappear. In accordance with normal tracking treatment, one will then have the appearance of target loss, system disorder, and bungled combat opportunities. Because of this, memory extrapolation tracking becomes very necessary.

Memory extrapolation is nothing else than making use of target information from the previous frame and this frame. In conjunction with this, storage memory is added. After that, use is made of predictive algorithms to forecast the target parameters in the next frame. The rest may be deduced by analogy. Extrapolation algorithms are very numerous. They have various advantages and disadvantages--for example, approximation /54 algorithms are simple and fast. However, accuracy is relatively bad. Kaerman (phonetic) wave filter methods are advanced, but computations are complicated. We opt for the use of "differential linear drafting extrapolation" methods. The basic important points are that imagery is reduced from three dimensions to two dimensions, inertial limited non stable processes, and blocking of previous tracking data (target center positions) which have already entered into processors (that is, memory algorithms). Once targets are lost, it is necessary, by processors making use of previous target information (existing memory), to predict the target's next position on the basis of differential linear

drafting extrapolation. Relying on this, they cycle right through to the target's appearance. A summary of the algorithm is as follows:

$$X(t_i) \quad y(t_i) \qquad i=0,\ 1,\ 2\cdots\cdots N-1$$

for a target at instant ti and coordinate x,y.

Doing differential differences,

$$\Delta X_i = X(t_i+1) - X(t_i)$$
$$\Delta y_i = y(t_i+1) - y(t_i)$$
$$i = 0,1,2,\cdots\cdots$$

Doing slope drafts (precisely specifying coefficient K)

-expected average method

$$\hat{K} = \sum_{i=0}^{N-1} \Delta X_i / N \qquad (8)$$

least square method

On the foundation of expected average methods, minimum square approximations were done on K to solve for basic values

$$\sum_{i=0}^{N-1} (\Delta X_i - \hat{K})^2/N = \varepsilon_f$$

$$\sum_{i-0}^{N-1} (\Delta X_i - \alpha\hat{K})^2/ = \varepsilon_a$$

for the condition $\alpha > 1$

Making K corrections

$$\sum_{i=0}^{N-1} (\Delta X_i - a\hat{K})^2/N = \varepsilon_l$$

for the condition $\alpha < 1$

Respectively comparing ε_f, ε_0, ε_1, use is made of recurrence methods to make values minimum. $\alpha\hat{K}$ which are obtained are minimum square approximate slope drafts (that is, draft quality is the best).

Δy_i can also be obtained in an analogous way.

Summarizing what was discussed above, on board infrared imagery recognition tracking is divided into two parts. One is target recognition extraction which primarily opts for the use of imagery processing and statistical decision making methods combined together for realization. The second is tracking which primarily opts for the use of self-adjusting tracking modes. When tracking requirements are low, selection was made of self- adjusting contrast tracking which is economical in practical use. When tracking requirements are high, target shape self-adjusting tracking is selected for use (matching wave filter).

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